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CA 2638480 A1 2010/02/01

(21) 2 638 480

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

(22) Date de dépôt/Filing Date: 2008/08/01

(41) Mise à la disp. pub./Open to Public Insp.: 2010/02/01

(51) Cl.Int./Int.Cl. *E01D 19/12* (2006.01),
B32B 19/02 (2006.01)

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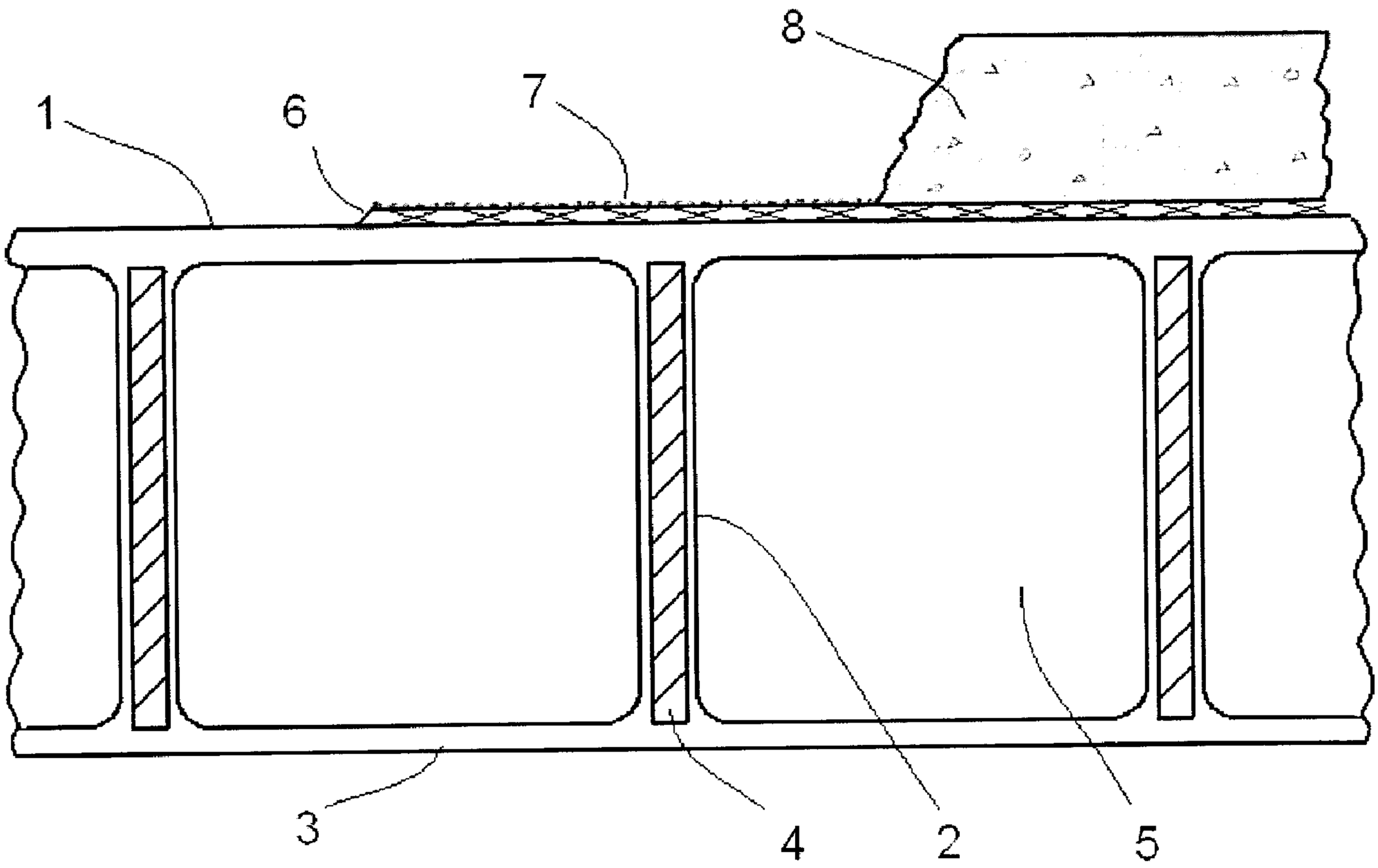
(54) Titre : PANNEAU DE COMPOSITES PREFABRIQUE
(54) Title: PREFABRICATED COMPOSITE PANEL



(57) Abrégé/Abstract:
A composite structure comprising a composite body member made of a composite material; and, a composite wear surface disposed on a surface of the composite body member, the composite wear surface comprising at least one layer of a fiber material infused with a resin and a hardener and prefabricated composite bridge deck panels made of fibre reinforced polymer composite for installation as a bridge deck for a bridge and a method for manufacturing prefabricated composite bridge deck panels.

ABSTRACT

A composite structure comprising a composite body member made of a composite material; and, a composite wear surface disposed on a surface of the composite body member, the composite wear surface comprising at least one layer of a fiber material infused with a resin and a hardener and prefabricated composite bridge deck panels made of fibre reinforced polymer composite for installation as a bridge deck for a bridge and a method for manufacturing prefabricated composite bridge deck panels.

PREFABRICATED COMPOSITE PANEL

FIELD OF THE INVENTION

The present invention relates to composite panels, and more particularly relates to prefabricated composite bridge deck panels made of fibre reinforced polymer composite for installation as a bridge deck for a bridge and relates to a method for manufacturing prefabricated composite bridge deck panels.

BACKGROUND OF THE INVENTION

Bridges are subjected to harsh environments, heavy loads and significant wear, and have historically required massive bridge decks (in the present context, a bridge deck being understood to mean the upper surface of the bridge upon which vehicular traffic travels and pedestrians walk, made of, for example, concrete or steel (or more recently, composite materials), and which, in some cases, may be provided with a top coating of asphalt or other road/bridge surfacing materials, to withstand the effects of the harsh environment and heavy loads on the bridge deck during the life of the bridge. Bridges of typical concrete and steel construction generally require significant maintenance and repair costs due to the effects of corrosion during their lifetime. Fibre-reinforced polymer (FRP) composites are widely recognized for their high strength to weight ratio, a high resistance to corrosion and low maintenance costs. When installing a new bridge deck on a either a new bridge, or on a bridge that is being refurbished or reconstructed, it is desirable to install a bridge deck that is substantially lighter than a correspondingly rated concrete or steel bridge deck, while at the same time, improving the bridge deck's ability to withstand the harsh environment and heavy loads to which it is expected be subjected. The reduced weight of the composite bridge deck also reduces the stresses and corresponding design and construction costs of the underlying bridge structure. Typical bridge construction projects require a significant amount of on-site time to fabricate and/or assemble the bridge deck, during which time there can be substantial disruption, inconvenience and cost to the transporting public.

Composite bridge deck panels have been in use in North America for more than a decade. Composite bridge decks are lighter, stronger, and more durable than comparably sized concrete

bridge decks. Many composite bridge deck systems consist of pultruded FRP elements that are adhered together into modular panels in the manufacturing plant. Composite FRP structures can be very efficient in their design with the orientation of reinforcing fibres; however this ability is limited in the pultrusion process, whereas the vacuum-assisted resin infusion process allows for the layout of specific fibre reinforcement orientations. In addition to its flexibility, the vacuum infusion process is more cost effective when compared to pultrusion, where cost efficiency depends on large scale production runs.

The remote manufacturing of a composite bridge deck reduces the cost and effort required relative to the typical on-site construction methods involving cast-in-place or precast concrete. The lightweight, prefabricated composite deck panels are easier to transport from the manufacturing location to the bridge construction/installation site, reducing the size of the crane or other lifting equipment required to lift and position the bridge deck panels onto the bridge support structure during construction, and reducing the strength requirements of the bridge support structure required to support the bridge deck.

Composite FRP deck panels are typically transported to the work site and installed in a number of sections, joined by adhesives, and then a wear surface is installed. The advantages of composite decks have been overshadowed by problems associated with the on-site installation, in particular, the application of, and materials used for wear surfaces. Construction joints between panels have proven to be problematic, where any relative movement can produce cracking, leaking and subsequent debonding in some wear surfaces. In some instances, asphalt road surfaces as thick as three inches have been layered over composite bridge decking. However, the application of an asphalt road surface several inches thick wholly or substantially negates the light weight design benefit of using composite material construction techniques. In other instances a thin wear surface of polymer concrete has been applied to the upper surface of the composite deck panels. While this complemented the need to reduce the weight of the bridge when compared to the application of a three inch thick layer of asphalt, nevertheless, in some instances, it was found that these thin synthetic wear surfaces were subject to cracking and debonding and required replacement within a short period of time, thereby driving the overall life cycle cost of the composite bridge deck higher than a conventional (concrete) bridge deck.

It is desirable to minimize the on-site time to construct or install a bridge.

It is desirable to provide a composite bridge deck panel having a durable non-skid wear surface that can withstand extensive use, and does not readily separate from the bridge deck panel..

It is also desirable to provide a bridge deck with as few construction joints as possible.

It is also desirable to provide a bridge deck which is not as susceptible to freezing before the adjacent roadways due to their exposed nature and the materials used.

It is also desirable to provide a bridge deck that freezes less quickly than a comparable concrete or composite bridge deck, reducing the risk of motor vehicle accidents and/or injury.

SUMMARY OF THE INVENTION

Accordingly, one object of the present invention is to provide a composite bridge deck panel having a durable non-skid wear surface that can withstand extensive use that does not readily separate from the bridge deck panel.

Another object of the present invention is to provide a bridge deck that freezes less quickly than a comparable concrete or composite bridge deck, reducing the risk of motor vehicle accidents and/or injury.

Another object of this invention is to produce large scale deck panels units that minimize the number of joints required to create a complete deck.

Another object of this invention is to provide a bridge deck that can be installed in a few days, rather than the months normally required.

According to one aspect of the present invention, there is provided a composite structure. The composite structure comprises a composite body member made of a composite material and a composite wear surface disposed on a surface of the composite body member. The composite wear surface comprises at least one layer of a fiber material infused with a resin and a hardener.

According to another aspect of the present invention, there is provided a composite panel comprising an upper plate and a lower plate. The upper plate and the lower plate are made of a

composite material. A plurality of support members is disposed between the upper plate and the lower plate. Each of the plurality of support members is made of a composite material and is connected to the lower plate at a first end and to the upper plate at a second opposite end. At least one of the support members comprises an internal structural core made of a different material.

According to yet another aspect of the present invention, there is provided a composite panel comprising an upper plate and a lower plate. The upper plate and the lower plate are made of a composite material. An end portion made of the composite material is connected to the upper plate and to the lower plate. The end portion is shaped for mating with a respective end portion of a second other composite panel. An upper surface of the end portion is recessed with respect to the upper plate for forming a depression when mated with the second other panel. The depression accommodates at least one layer of resin and reinforcement material having a predetermined thickness therein.

An advantage of the present invention is that it provides a composite bridge deck panel having a non-skid wear surface that can withstand extensive use that does not readily separate from the bridge deck panel while enhancing the structural properties of the bridge deck panel.

In addition to providing a tough, durable base for the non-slip surface of compatible aggregate, the basalt fibre layer also creates a fire-resistant barrier.

A further advantage of the present invention is that it provides a composite bridge deck with a minimum number of construction joints, thereby reducing the likelihood of joint related problems and maintenance costs.

Another advantage of this invention is that the bridge deck can be transported to the site in small number of pieces and installed on the supporting girder framework as a “rapid-bridge construction” solution.

A further advantage of the present invention is that due to the materials used, it provides a bridge deck that freezes less quickly than a comparable concrete or composite bridge deck, reducing the risk of motor vehicle accidents and/or injury.

BRIEF DESCRIPTION OF THE DRAWINGS

An embodiment of the present invention is described herein with reference to drawings, in which:

Figure 1 is a partial cross-sectional view of a portion of the bridge deck panel of one embodiment of the present invention;

Figure 2A is a detailed cross-sectional view of the laminate layer configuration of the upper plate and wear surface in the preferred embodiment of the present invention;

Figure 2B is a detailed cross-sectional view of the laminate layer configuration of the vertical support in the preferred embodiment of the present invention;

Figure 2C is a detailed cross-sectional view of the laminate layer configuration of the lower plate in the preferred embodiment of the present invention;

Figure 3A is a cross-sectional view of one side of the "L-shape" type deck panel joint;

Figure 3B is a cross-sectional view of the other side of the "L-shape" type deck panel joint;

Figure 3C is a cross-sectional view of the sides of the "L-shape" type deck panel joint joined together;

Figure 4A is a cross-sectional view of one side of the "C-shape" type deck panel joint;

Figure 4B is a cross-sectional view of the other side of the "C-shape" type deck panel joint;

Figure 4D is a cross-sectional view of the sides of the "C-shape" type deck panel joint joined together;

Figure 5A is cross-sectional view of a typical crowned bridge deck with a longitudinal in deck panel joint detail with an upper recess for joining laminates in the top plate;

Figure 5B is an enlarged cross-sectional view of a portion of a bridge deck with an upper recess for joining laminates in the top plate;

Figure 6 is a cross-sectional view of a longitudinal bridge superstructure supporting girder and showing deck panel connection layout;

Figure 7A is a top view of a portion of a fixed connection showing anchor studs for deck to girder attachment;

Figure 7B is a cross-sectional view of a portion of a fixed connection showing anchor studs for deck to girder attachment;

Figure 8 is a perspective view of bridge deck panel sliding connection clip;

Figure 9A is a top view of a retaining wall in an alternative embodiment of the present invention;

Figure 9B is a side view of a retaining wall in an alternative embodiment of the present invention; and,

Figure 9C is a cross-sectional view of a retaining wall in an alternative embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

While embodiments of the invention will be described for composite bridge deck panels only for the sake of simplicity, it will become evident to those skilled in the art that the embodiments of the invention are not limited thereto, but are employable in other applications such as, for example, in roof structures and floor structures of buildings.

Referring to Figure 1, in a preferred embodiment of the present invention, a bridge deck panel is provided for installation on a bridge structure with one or more other bridge deck panels to form a bridge deck (it being understood that in the context of small bridges, a single bridge deck panel may be used). In one embodiment of the present invention the bridge deck panel measures approximately 8 feet in length – in the direction of the bridge, 16 feet in width – in the direction transverse to the bridge, and 8 inches in thickness, it being understood that a wide range of differently sized and shaped bridge deck panels may be made and installed in accordance with the present invention.

In a preferred embodiment of the present invention, as illustrated in Figures 1 and 2 each of the bridge deck panels has an upper plate 1, a lower plate 3, a plurality of vertical or substantially vertical support members 2 extending upwardly from a lower plate 3, joining the upper surface of the lower plate 3 with the lower surface of the upper plate 1. Optionally, the support members 2 are oriented other than vertical or substantially vertical, for example, oriented such that two support members 2 intersect when joining the upper plate 1 or the lower plate 3. The vertical support elements 2 comprise a resin matrix with a structural core material 4, generally reinforced with double bias (+/- 45) layers and chopped strand mat and vertical uni-directional e-glass reinforcements. The upper 1 and lower 3 plates comprise a resin matrix and sheets of reinforcing fibres, with the majority oriented in longitudinal directional (uni-directional) with some double bias (+/- 45) layers and chopped strand mat. Of course, in alternative embodiments of the present invention as described herein a wide range of alternative fibres and materials may be used which have been infused with resin (preferably a vinyl-ester based resin, it being understood that in alternative embodiments of the present invention a wide range of alternative resins such as polyester, isophthalic or epoxy may alternatively be used) to which resin an appropriate quantity of an appropriate hardener has been added.

In one embodiment of the present invention, as illustrated in Figures 2A to 2C, sheets or layers of double bias electrical grade glass fibre 20, biaxial electrical grade glass fibre 21, chopped strand electrical grade glass fibre 22 and a layer of basalt fiber 23 may be layered and oriented so as to maximize the overall compression, tension and shear properties of the completed bridge and enable the deck structure to carry the applicable design loads in accordance with bridge design specifications such as the Canadian Highway Bridge design code.

In a preferred embodiment of the present invention, the vertical support members 2 may be resin infused glass fibre, and, as illustrated in Figure 1, have an internal structural core 4 such as Divinicell H80. Other structural cores comprising foam or reinforced plastic or wood products such as oriented strand board (OSB) or combinations thereof may also be used. Where the vertical support members 2 abut the upper plate 1 and lower plate 3, additional glass or basalt fibre reinforcement may be applied as illustrated in Figures 1 to increase the strength of the joint therebetween.

In one embodiment of the present invention, the entire upper surface of the upper plate presents a raised pattern thereon to provide a non-smooth surface to which asphalt 8 or another material may be applied, the raised pattern enhancing the mechanical connection with the upper surface of the deck panel, in the event that a layer of asphalt is to be applied to the top of the panel, reducing the likelihood that the asphalt will move relative to the upper plate once applied.

In a preferred embodiment of the present invention, a composite wear surface 6 is provided (a portion of which is illustrated in Figure 1) which is integral with the upper surface of the upper plate 1, the composite wear surface 6 preferably being formed of one or more layers of basalt fibers (it being understood that alternative fibers may be used to form the wear surface) infused with preferably a high modulus vinyl-ester resin and an appropriate quantity of hardener. Additionally, the composite wear surface 6 integral with the upper surface of the upper plate 1 provides additional strength to the deck panel and increases the fire resistance of the deck surface. Additionally, the composite wear surface 6 readily accepts on the upper surface thereof, a layer 7 of, for example, synthetic olivine granular as illustrated in Figure 1 which may be infused with or applied to the upper surface of the composite wear surface 6 by, for example, providing a thin layer 7 of resin mixed with synthetic olivine granular to the upper surface of the composite wear surface 6 prior to the full curing of the resin infused during the process of forming the composite wear surface 6. In this embodiment of the present invention, the upper surface of the composite wear surface 6 is textured to provide a high friction surface to provide traction for motor vehicles and pedestrians using the bridge. In one embodiment of the present invention, a basalt fibre wear surface having a synthetic olivine granular upper surface is provided separately, for example, as a tile or plate, for installation on or application to a new or existing bridge deck (which new or existing bridge deck may be made of concrete, steel or composite material).

This invention introduces the use of basalt fibre with embedded aggregate as a wear surface. Basalt fibre is an environmentally friendly inorganic fibre, produced from basalt rock, with mechanical properties that significantly exceed e-glass. Basalt granulars have been used in road construction for centuries and are known for their hardness and durability. The basalt fibre and aggregate wear surface and FRP deck panel are fabricated by infusion during a vacuum-assisted resin infusion process. This process and method creates panels consisting of a top plate with wear surface, and bottom plates and vertical supports in a monolithic unit. This structural panel also utilizes vertical supports with structural sandwich core materials.

In a preferred embodiment of the present invention, the hollow passageways formed by the vertical members and the upper and lower plates may be filled with insulation 5, such as, for example, polyisocyanurate insulation (or such other insulation known to a person skilled in the art) to reduce the likelihood of the early freezing of the bridge's deck road surface.

Optionally, the insulated composite panel is employable as an insulating roof panel, for example, for lightweight flat roof structures of large buildings or as insulating floor structures of buildings constructed, for example, in regions with permafrost.

Referring to Figures 3A to 3C, in a preferred embodiment according to the invention each composite bridge deck panel comprises an end portion 30 for mating with a respective end portion 31 of a second other composite bridge deck panel. An upper surface 32 of the end portions 30 and 31 is recessed with respect to the upper plate 1 forming a depression 33 when mated with the second other panel. The depression has a predetermined thickness for accommodating at least one layer of resin and reinforcement material therein. As illustrated in Figure 3, the composite bridge deck panels may be joined by an "L-shape" type connection, which has one panel with a lower laminate plate extension and top plate depression that geometrically matches a lower plate recess and upper plate depression in the adjoining panel, with the top recess depth to accommodate a "hand layup" overlay 9 of resin and reinforcements equivalent to the top plate structure and a basalt 6 -olivine sand 7 wear surface, and where a structural adhesive 10 such as methacrylate or epoxy is applied to the contact surfaces to create a bonded connection.

As illustrated in Figures 4A to 4C, an alternate connection method to join bridge deck panels

utilizes a "C-shape" on one panel, where the horizontal upper 1 and lower plate 3 are extended beyond the outermost vertical support 2, whereas the adjoining panel has upper and lower plate recesses 40 and 41 to match the "C" extensions, and a structural adhesive 10 such as methacrylate or epoxy is applied to the contact surfaces to create a bonded connection. Optionally, the top surface of each of the end portions for mating the bridge deck panels are recessed with respect to the upper plate 1 to form a depression when mated, as in the embodiment illustrated in Figure 3.

As illustrated in Figures 5A and 5B, the bridge deck panels 50 are installed on the supporting girders 13 in a simple 2-lane structure, constructed so as to create a higher elevation or crown at the longitudinal centerline 52 of the deck which may be secured directly to the upper surface 53 of the bridges "I" beams or bridge support girders 13 by way of, for example, a connection clip 11 such as illustrated in Figure 8 secured by lag screws and structural adhesive to the lower surface of the lower plate of the deck panel, creating vertical and lateral restraint while allowing limited longitudinal horizontal translation to accommodate differential thermal expansion of the deck panel relative to supporting girders. The larger scale centerline joint detail in Figure 5B illustrates the longitudinal connection between adjacent deck panels 50 where each panel has a depression in the upper plate at a depth equal to the upper plate thickness and the depression is filled with a hand-layup laminate structure 9 equivalent to the upper plate 1, overlain with a basalt/olivine sand wear surface 7. Figure 5B also describes the adhered surfaces of the outermost vertical supports of each panel, connected by structural adhesive 10 such as methacrylate or epoxy and the levelling or filler material 12, that may be comprised of grout or fiber-reinforced polymer, that provides a bearing surface under the lower surface of the lower plate 3, on top of the supporting girder 13. It is understood that other geometric configurations are possible, where deck top elevations could be progressively higher across the full width of the bridge or level or some combination thereof as may be required for road design and drainage control.

As illustrated in Figure 6, the composite bridge deck can be connected to supporting girders 13 by connection clips 11 or threaded studs 16, or some combination thereof.

The fixed connection detail as illustrated in Figures 7A and 7B, is composed of threaded steel studs 70 welded to the top surface of the top flange of the supporting girder 13, projecting

through openings in the lower plate of the deck panel, where a steel nut 17A and washer 17B are installed through corresponding circular openings 15 in the upper plate and a cavity in the insulating foam creating a stud pocket 14, accessed and tightened to apply clamping force on the lower plate 3, above the levelling/filler material 12, that may be comprised of grout or fiber-reinforced polymer, with the stud pocket volume 14 to be later filled with grout or fiber-reinforced polymer and upper plate stud access opening 15 later reinstated with cutout upper plate material 71 and adhesive/sealant 10 of epoxy or methacrylate. The number and location of fixed connection points is subject to bridge project specific requirements.

As illustrated in Figure 5, 6 & 8, the connection clip 11 is fastened by lag screws through holes 11A provided in the connection clip and structural adhesive to the lower surface of the lower plate of the deck panel. The connection clip 11 constrains vertical and lateral horizontal movement of the bridge deck panel relative to the supporting girders. The geometry and configuration of connection clips are specific to bridge project requirements and supporting girder dimensions.

The connection details of Figures 7 & 8 represent "known art" to those familiar with composite bridge deck structure construction.

In a further alternative embodiment of the present invention, composite curb panels (not shown) may be provided, created using the same general methodology and materials described herein, and having a physical structure corresponding to a street curb adapted to connected to the appropriate walls of the bridge deck panels by glue or other adhesive to provide a curb for the bridge deck being constructed.

In a preferred embodiment of the present invention, the deck panels are manufactured using a vacuum assisted resin transfer infusion process to distribute the resin and "wet out" the fiber reinforcements, it being understood that alternative methods may be used to infuse the unhardened resin in a manner known to a person skilled in the art.

While the present invention has been described with reference to panels which may be joined together as described herein to form a bridge deck on a bridge structure, it is understood that the present invention may be used on bridges where only a single deck panel is required (the deck

panel dimensions being modified as appropriate for that application, and where appropriate, the joint wall may be replaced by a flat vertical end wall) or for a supported pedestrian bridge deck. In an alternative embodiment of the present invention, the bridge deck panel may be self-supporting for use in the context of relatively short bridge spans, without the need of a support "I" beam or girder. In a further alternative embodiment of the present invention, the one or more panels may be used to construct loading ramps, a deck for a wharf, a parking lot or parking garage deck, and in other similar applications where a large, strong and substantially flat surface is required.

In a further embodiment of the present invention, one or more panels may be used to form, for example, barrier or retaining walls such as illustrated in Figures 9A, 9B and 9C, where one or more deck panels 2A are positioned in a vertical orientation between, for example, two vertical support "H" piles 99 mounted on the ground 101 which are adapted to receive and support the deck panels in the vertical orientation in a conventional manner (in this embodiment of the present invention, "C-shape" Figure 3 joints are provided in place of the side walls, the end walls preferably having no step lap joints provided thereon).

The present invention has been described herein with regard to preferred embodiments. However, it will be obvious to persons skilled in the art that a number of variations and modifications can be made without departing from the scope of the invention as described herein.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A composite structure comprising:
a composite body member made of a composite material; and,
a composite wear surface disposed on a surface of the composite body member, the composite wear surface comprising at least one layer of a fiber material infused with a resin and a hardener.

2. A composite structure as defined in claim 1 wherein the fiber material comprises basalt fibers.

3. A composite structure as defined in claim 2 wherein the composite wear surface comprises embedded aggregate.

4. A composite structure as defined in claim 1 wherein the resin is a high modulus vinyl-ester resin.

5. A composite structure as defined in claim 1 comprising a layer of a granular material disposed onto the composite wear surface.

6. A composite structure as defined in claim 5 wherein the layer of granular material comprises a layer of resin mixed with a synthetic olivine granular material.

7. A composite structure as defined in claim 5 wherein the composite wear surface is textured to provide a high friction surface.

8. A composite structure as defined in claim 1 wherein the composite body member comprises:
an upper plate and a lower plate, the upper plate having the composite wear surface disposed thereupon; and,

a plurality of support members disposed between the upper plate and the lower plate, each of the plurality of support members being connected to the lower plate at a first end and to the upper plate at a second opposite end.

9. A method comprising:
providing a composite body member made of a composite material; and,
disposing a composite wear surface onto a surface of the composite body member, the composite wear surface comprising at least one layer of a fiber material infused with a resin and a hardener.

10. A method as defined in claim 9 wherein disposing the composite wear surface comprises infusing basalt fibers with the resin and the hardener.

11. A method as defined in claim 9 comprising embedding aggregate in the composite wear surface.

12. A composite panel comprising:
an upper plate and a lower plate, the upper plate and the lower plate being made of a composite material; and,
a plurality of support members disposed between the upper plate and the lower plate, each of the plurality of support members being made of a composite material and being connected to the lower plate at a first end and to the upper plate at a second opposite end, at least one of the support members comprising an internal structural core made of a different material.

13. A composite panel as defined in claim 12 wherein the internal structural core is made of Divinicell H80.

14. A composite panel comprising:
an upper plate and a lower plate, the upper plate and the lower plate being made of a composite material; and,
an end portion made of the composite material and being connected to the upper plate and to the lower plate, the end portion being shaped for mating with a respective end

portion of a second other composite panel, an upper surface of the end portion being recessed with respect to the upper plate for forming a depression when mated with the second other panel, the depression for accommodating at least one layer of resin and reinforcement material having a predetermined thickness therein.

15. A composite panel as defined in claim 14 wherein the at least one layer of resin and reinforcement material is equivalent to the structure of the upper plate.

16. A method comprising:

providing a first composite panel and a second composite panel, each composite panel comprising:

an upper plate and a lower plate, the upper plate and the lower plate being made of a composite material; and,

an end portion made of the composite material and being connected to the upper plate and to the lower plate, the end portion being shaped for mating with a respective end portion of the other composite panel, an upper surface of the end portion being recessed with respect to the upper plate for forming a depression when mated with the other panel, the depression for accommodating at least one layer of resin and reinforcement material having a predetermined thickness therein;

mating the first composite panel and the second composite panel;

bonding the first composite panel and the second composite panel; and,

disposing the at least one layer of resin and reinforcement material in the depression.

Application number / numéro de demande: 2638480

Figures: 6

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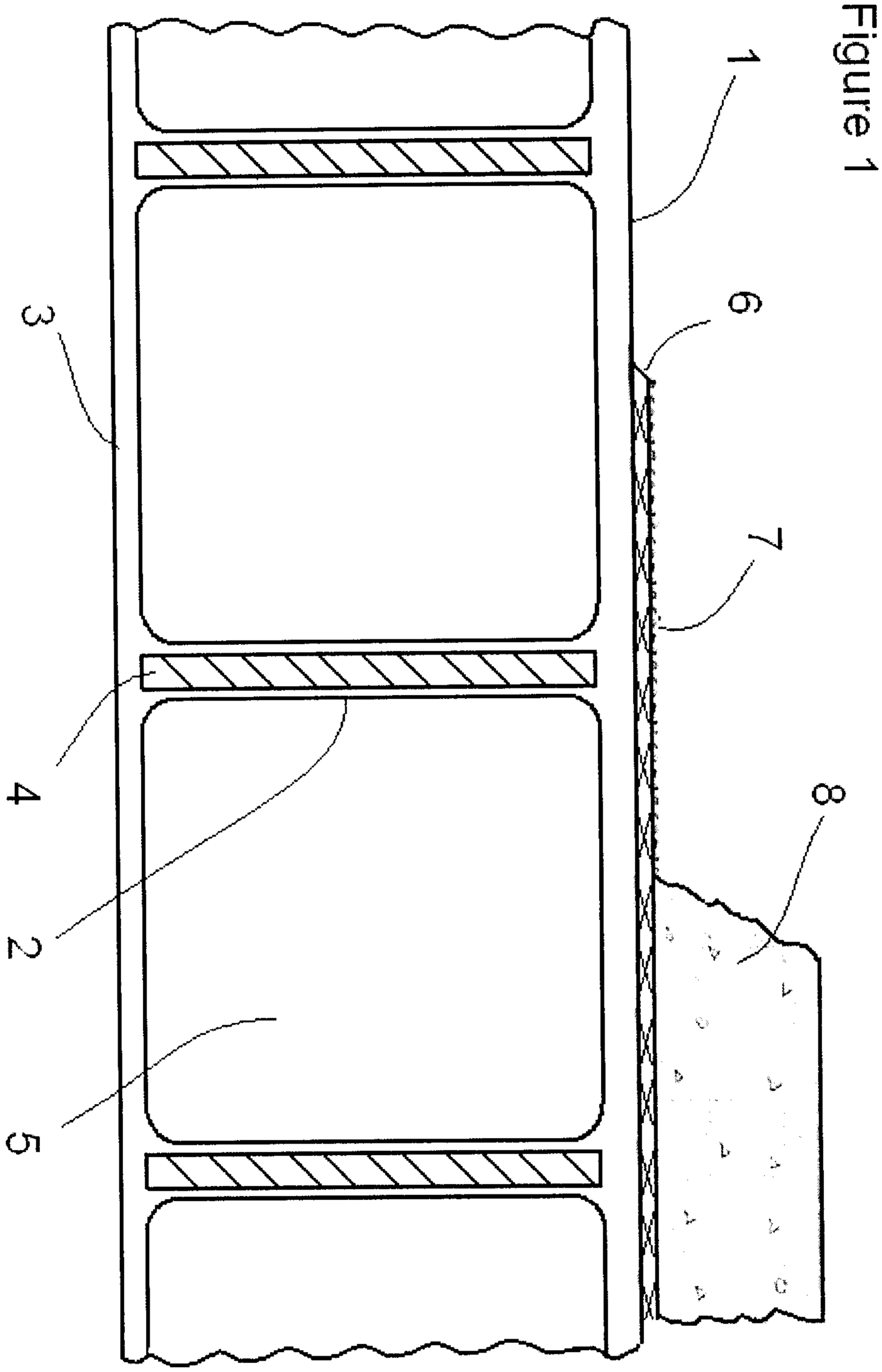


Figure 1

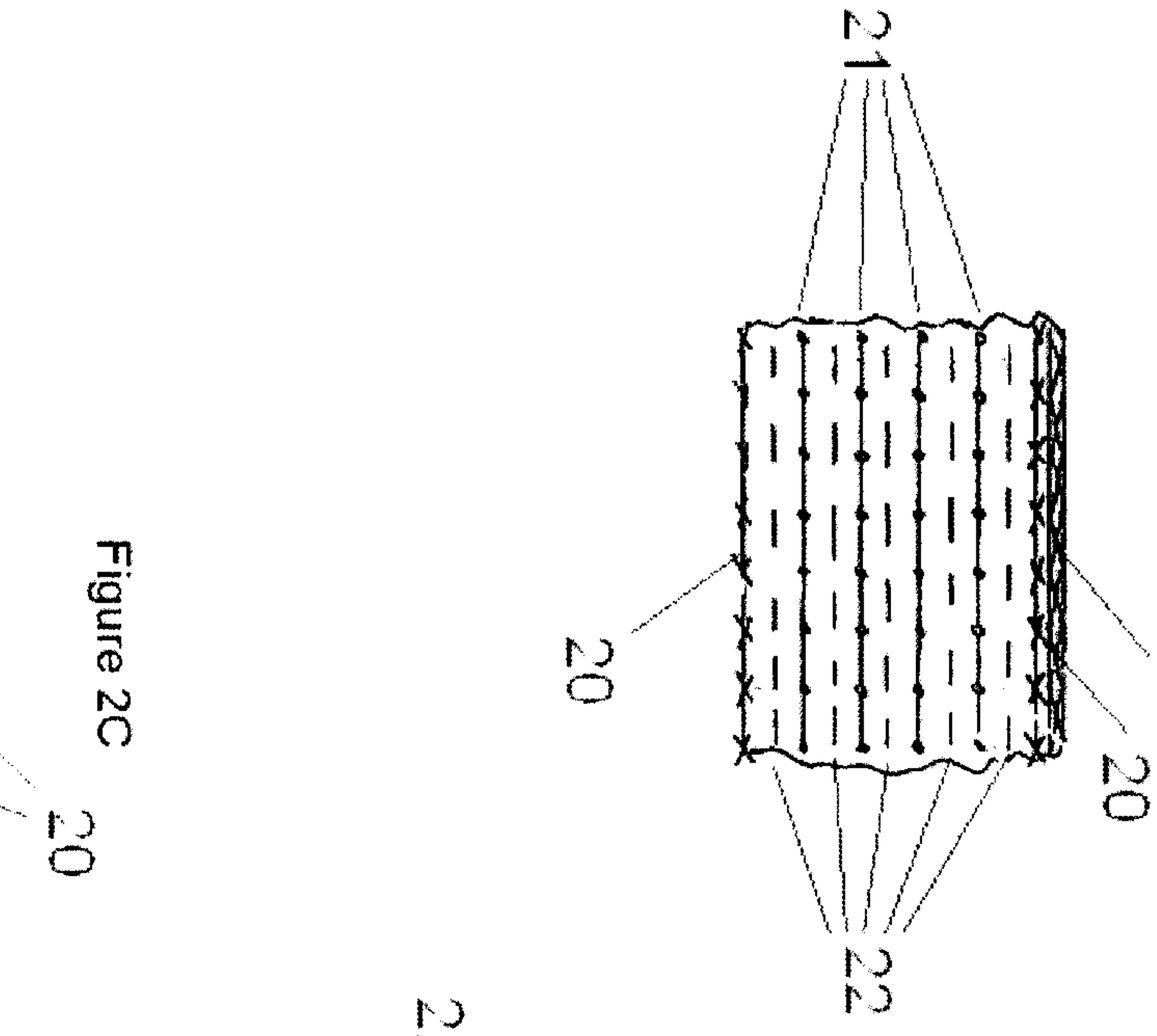


Figure 2A

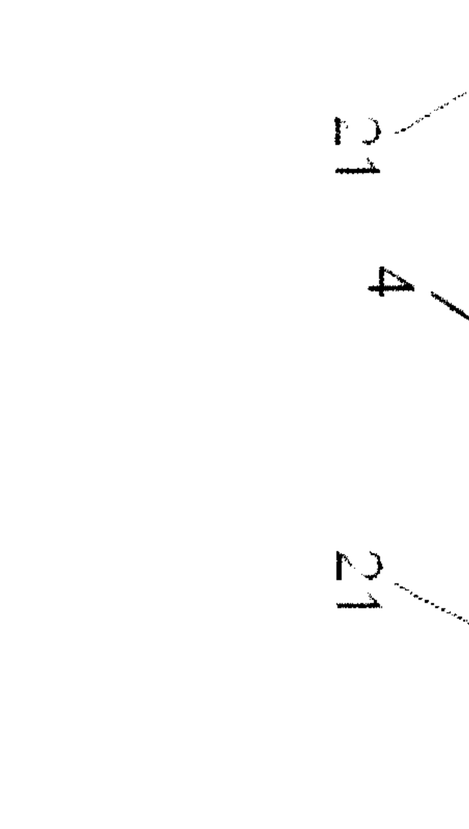


Figure 2C

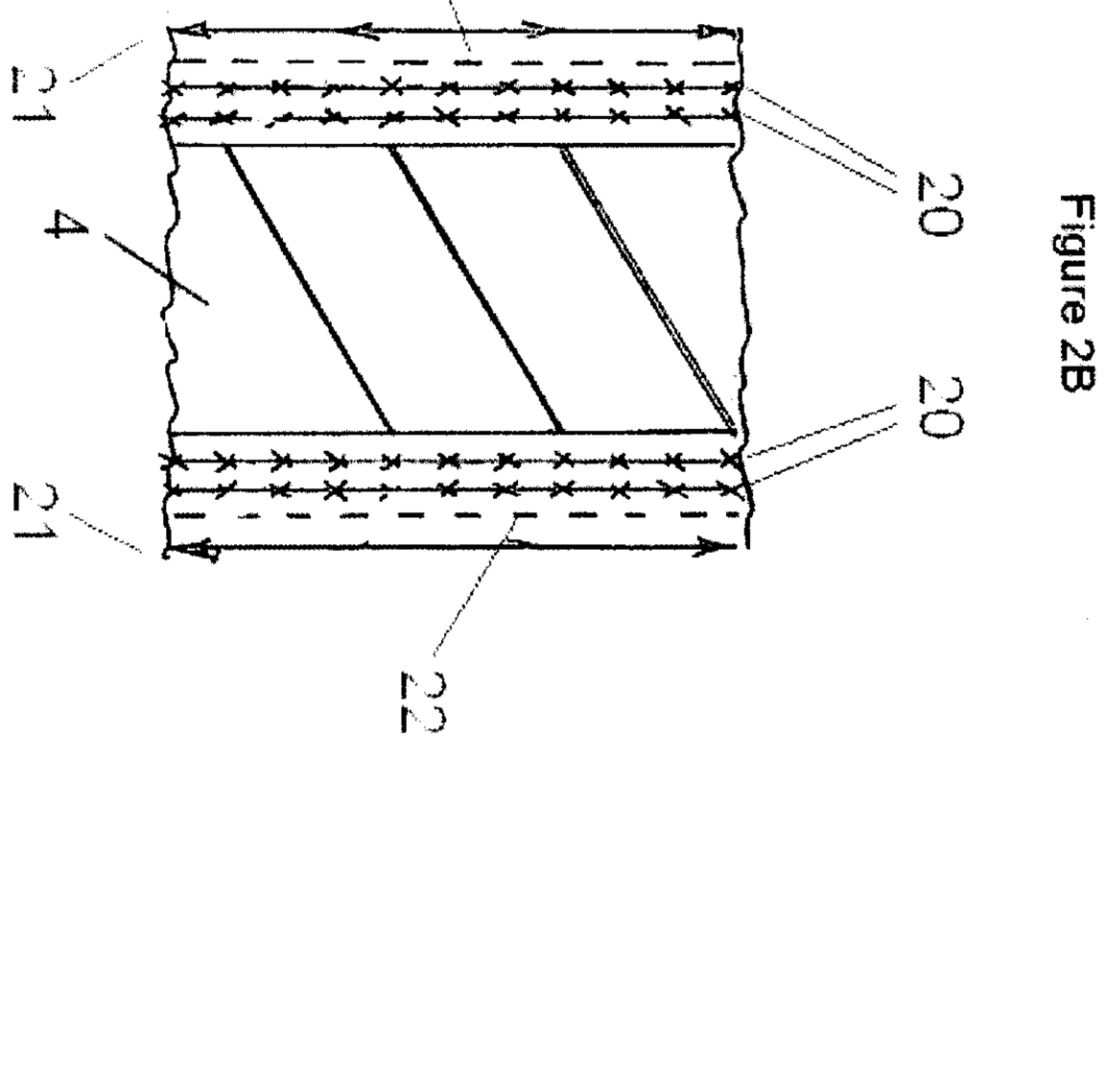


Figure 2B

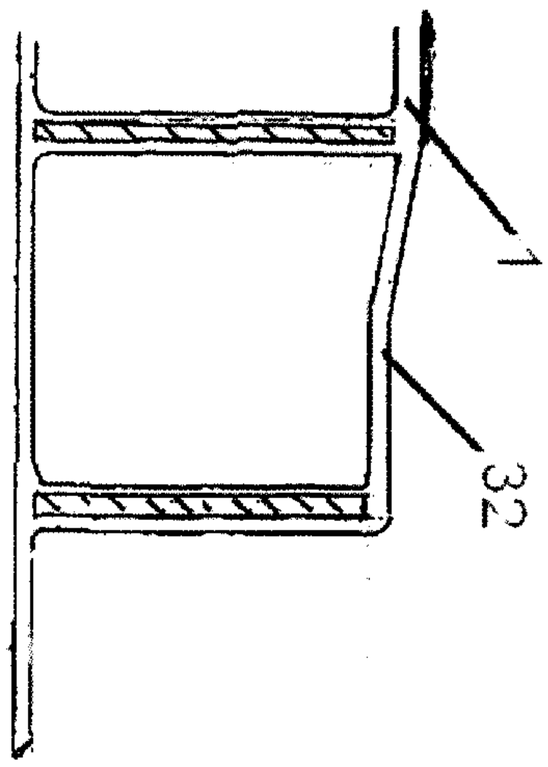


Figure 3A

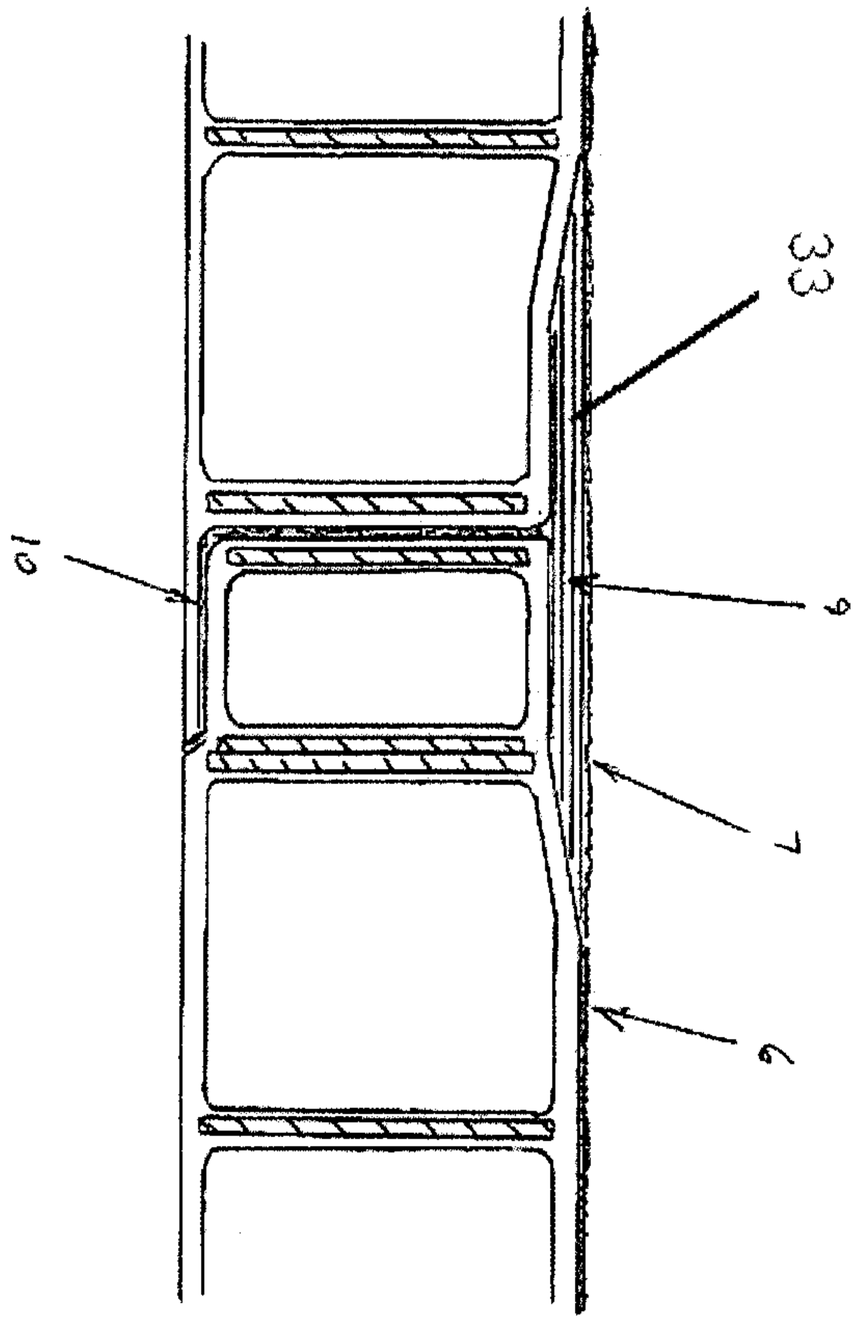


Figure 3C

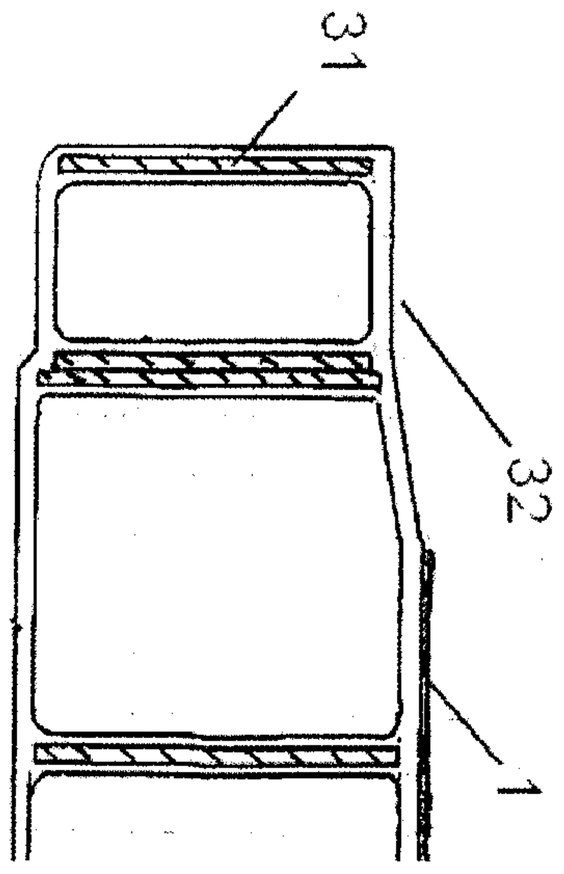


Figure 3B

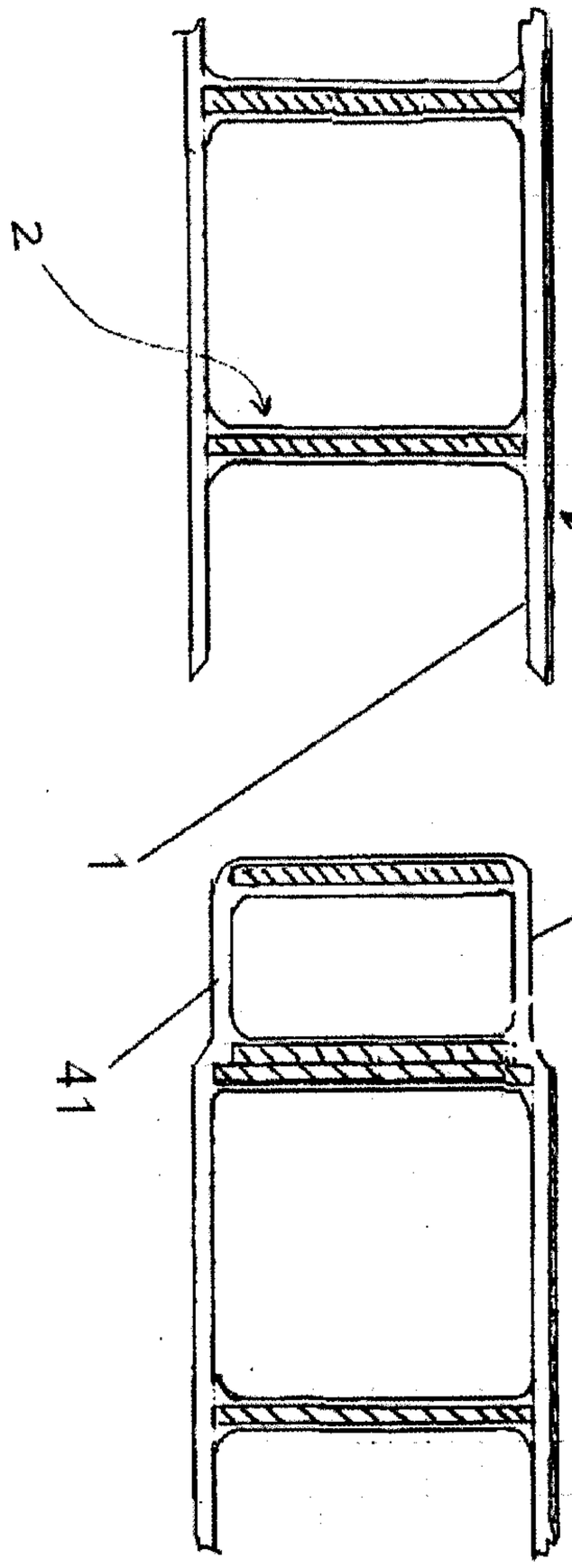


Figure 4A

Figure 4B

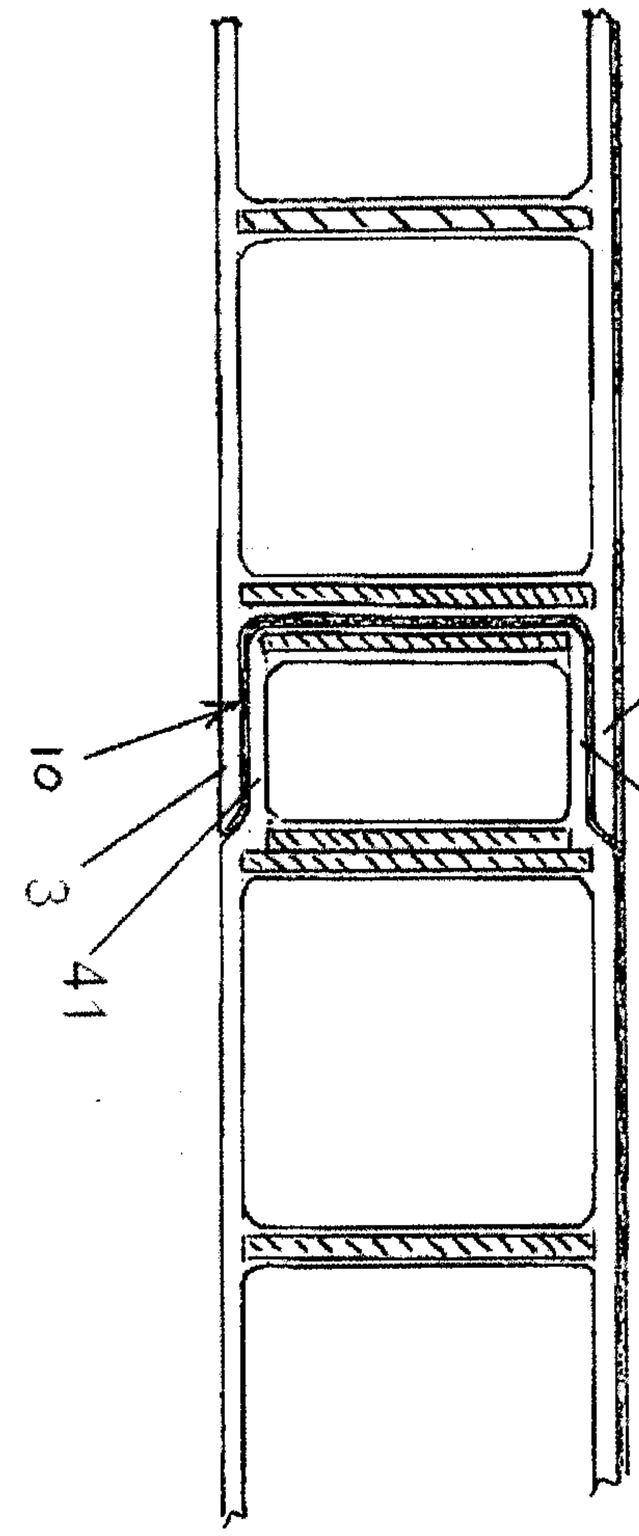


Figure 4C

Figure 5A

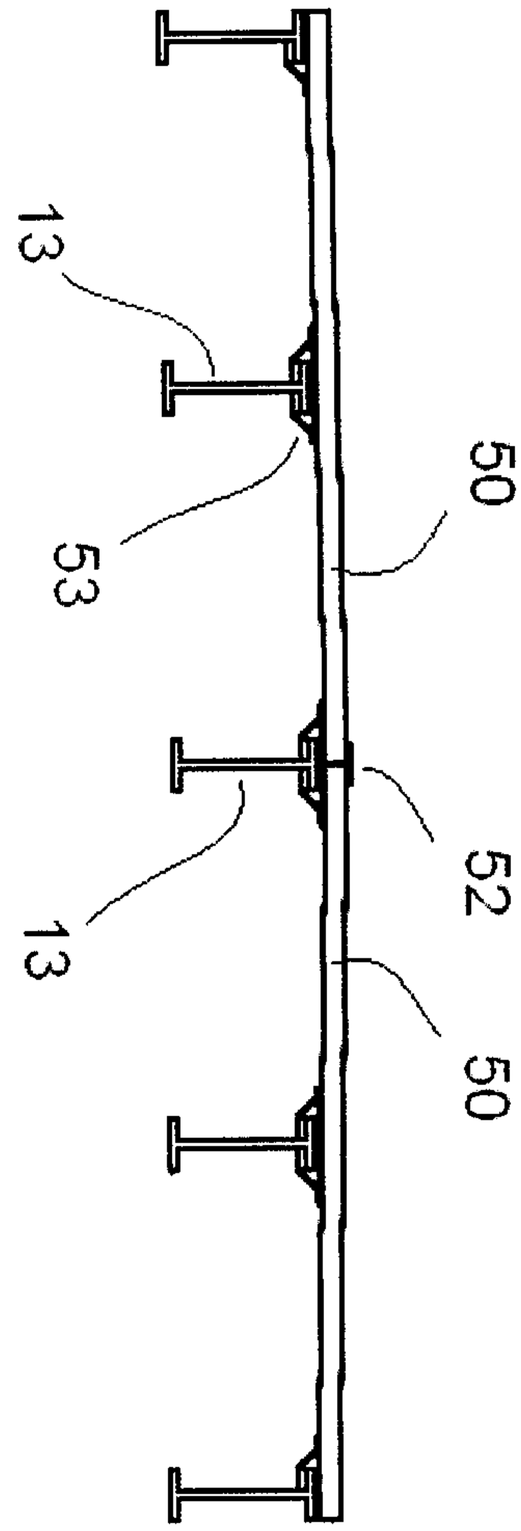


Figure 5B

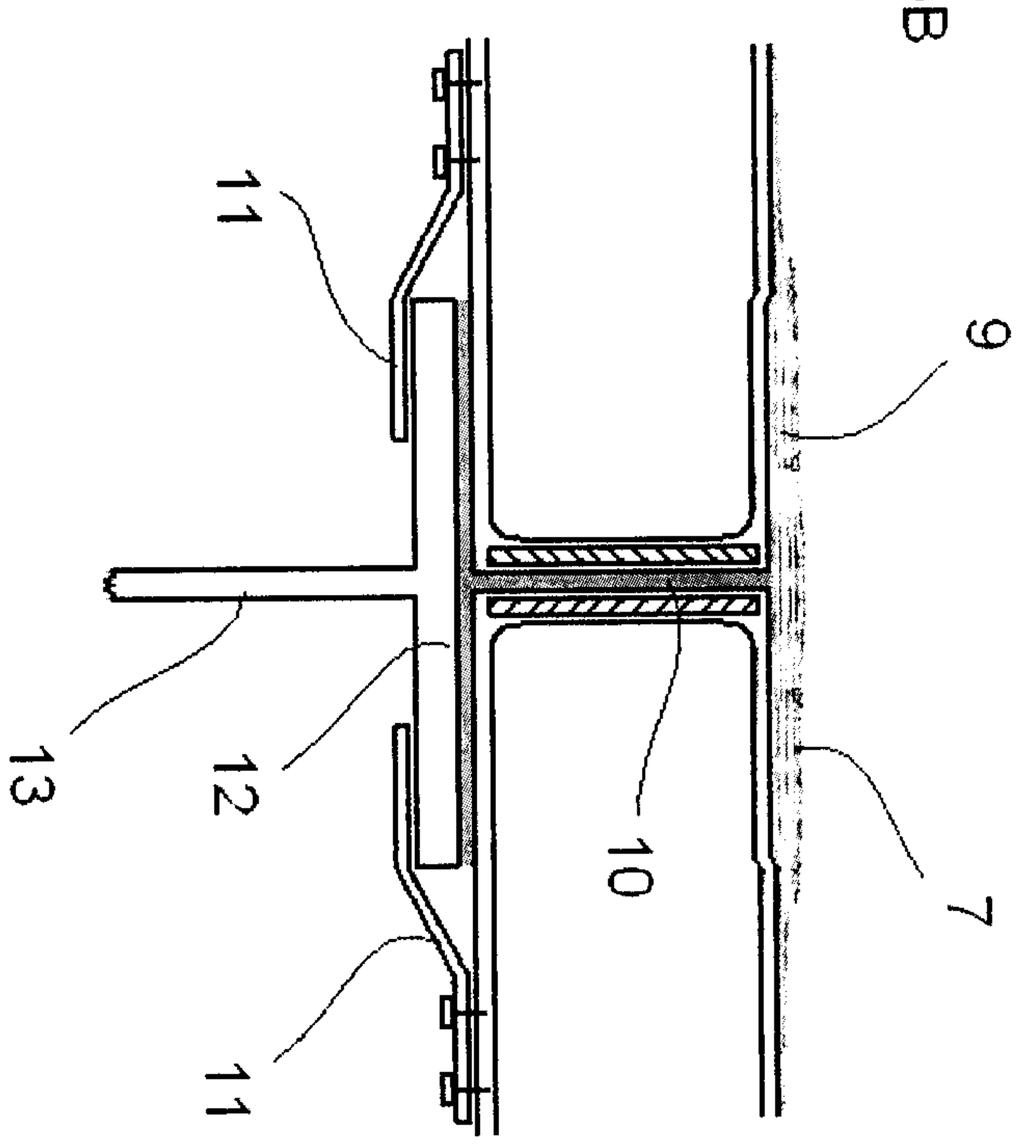


Figure 7A

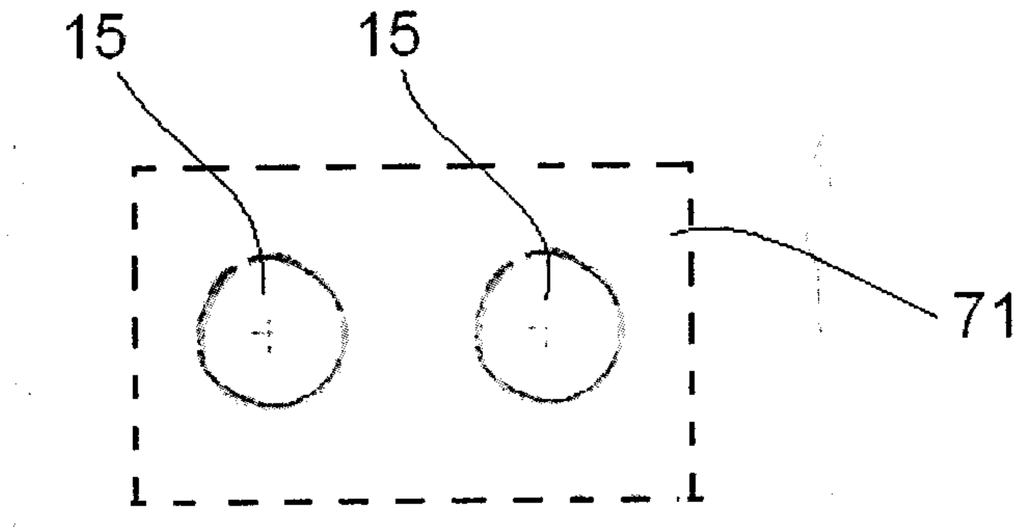
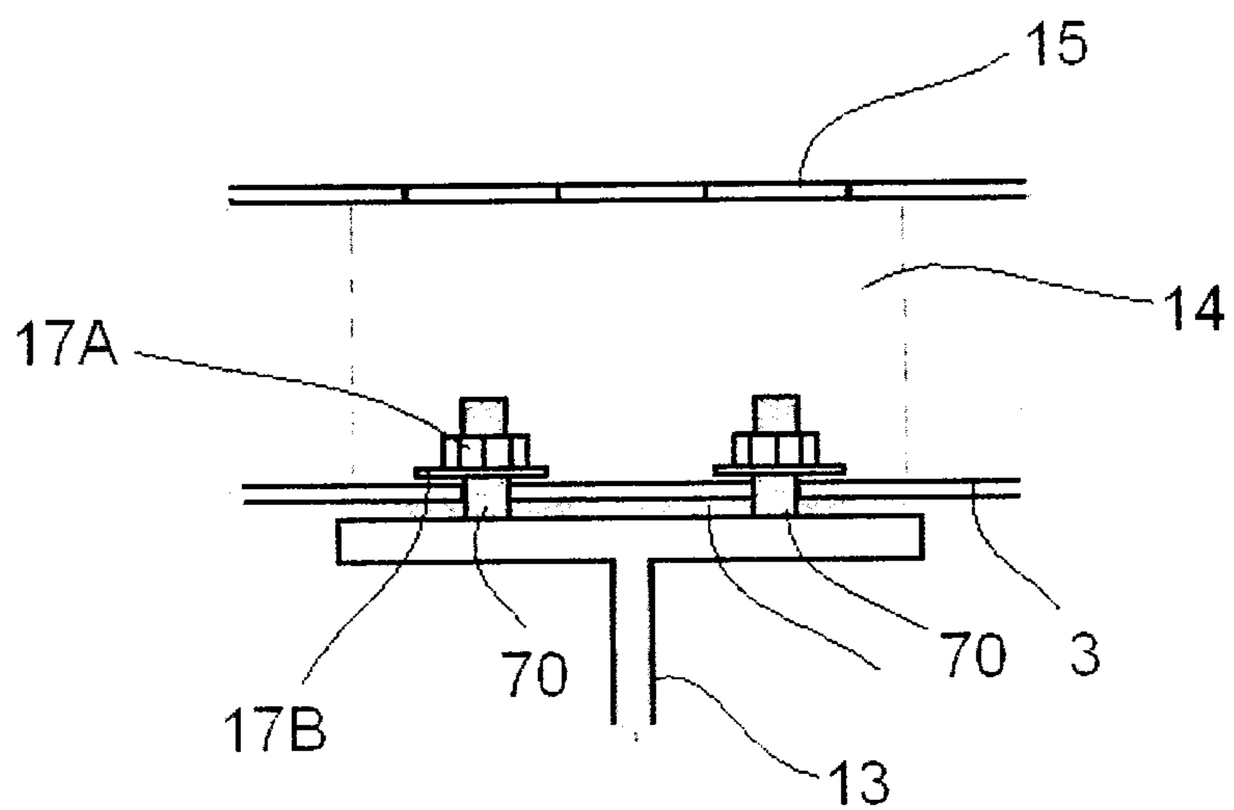


Figure 7B



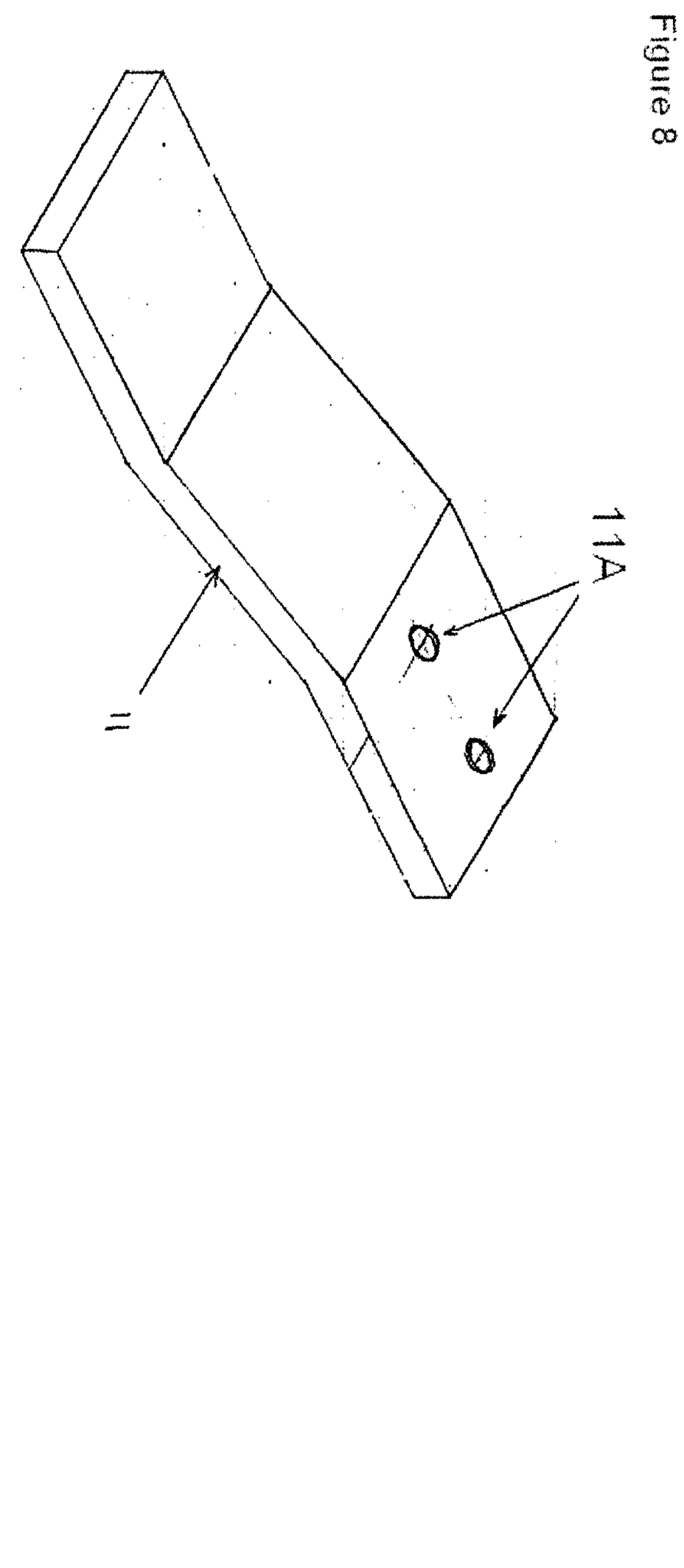


Figure 8

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Figure 9A

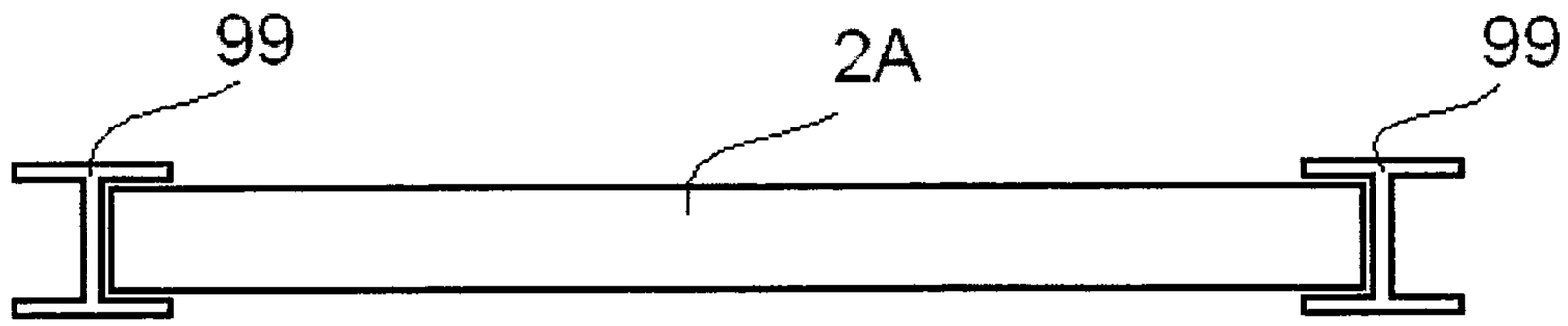


Figure 9B

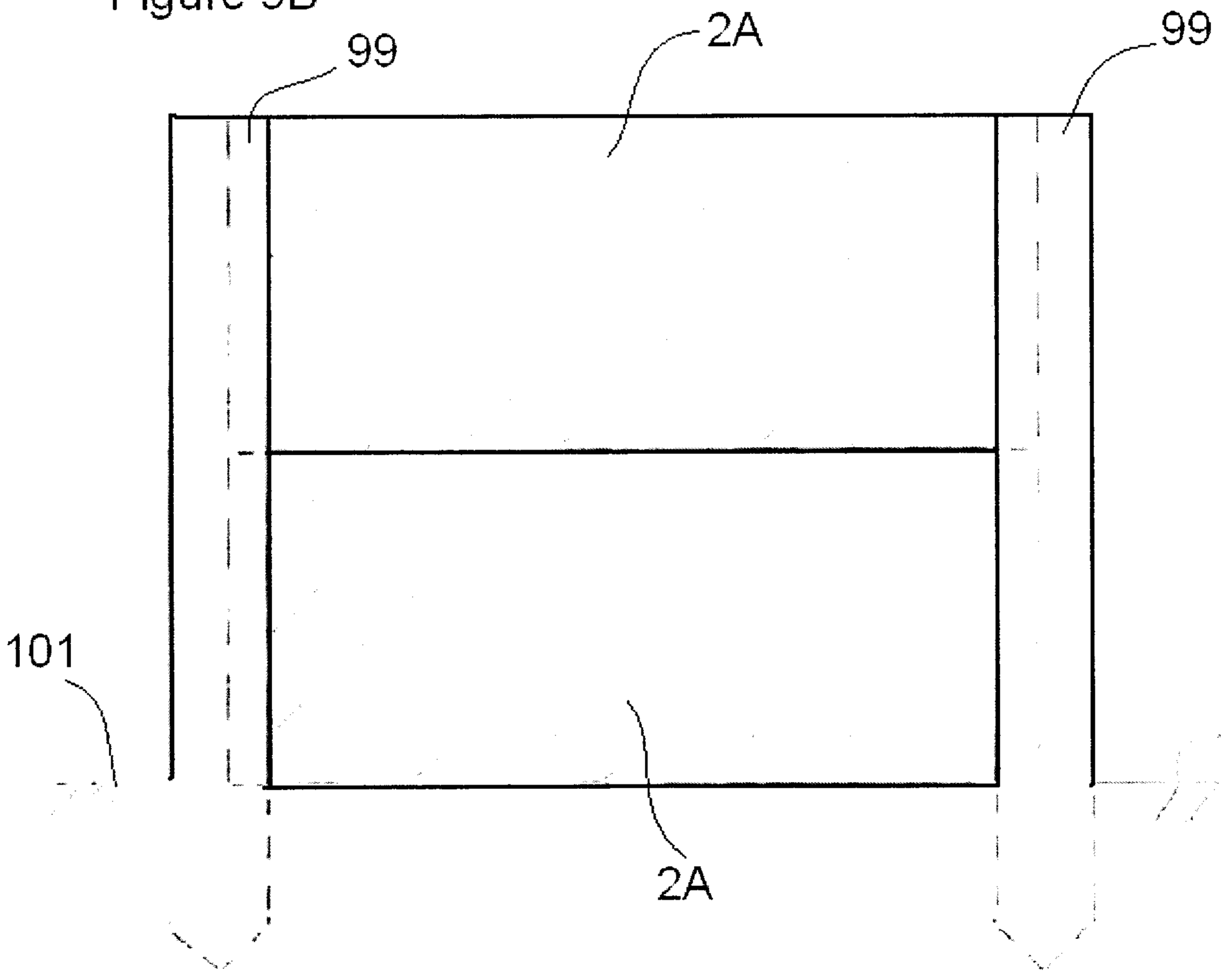
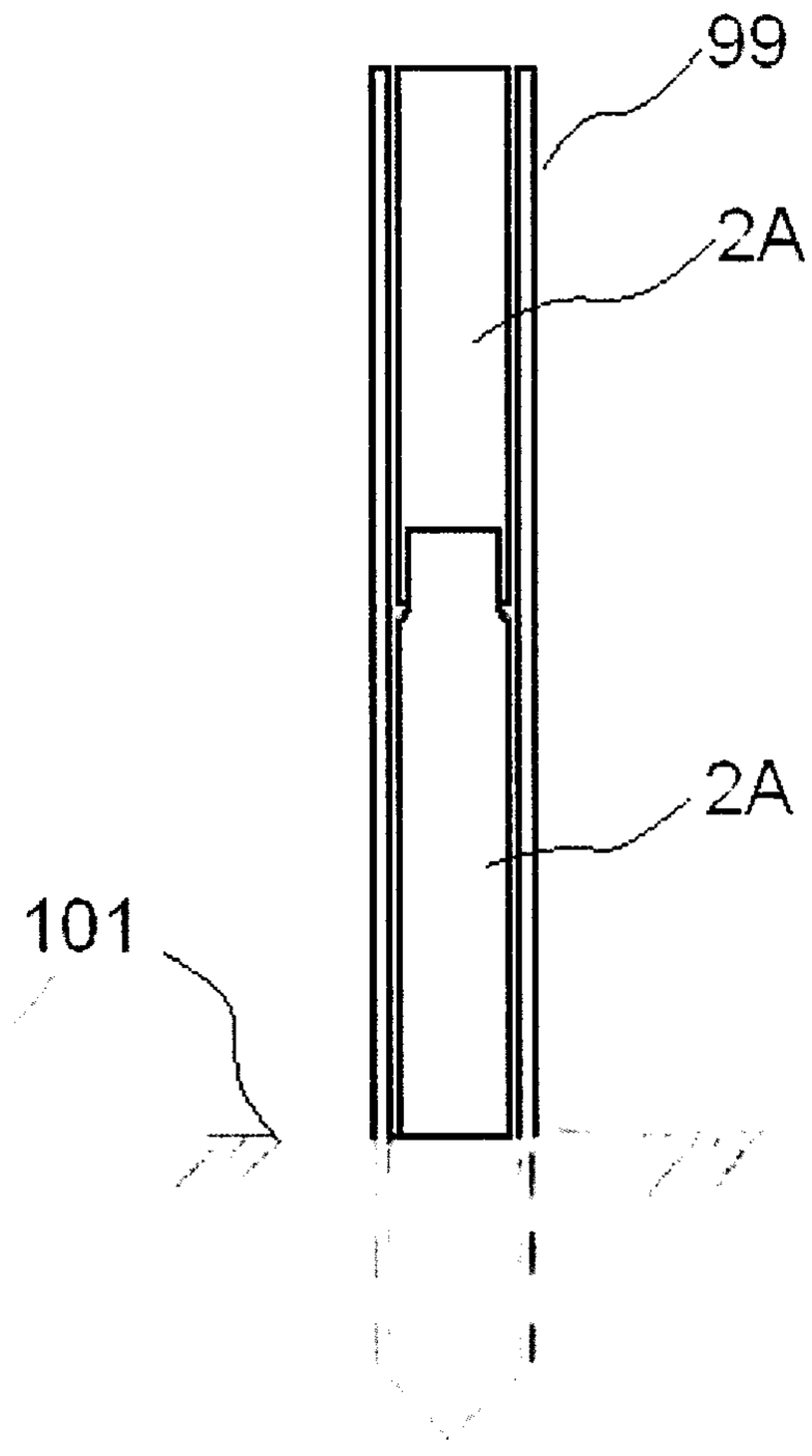
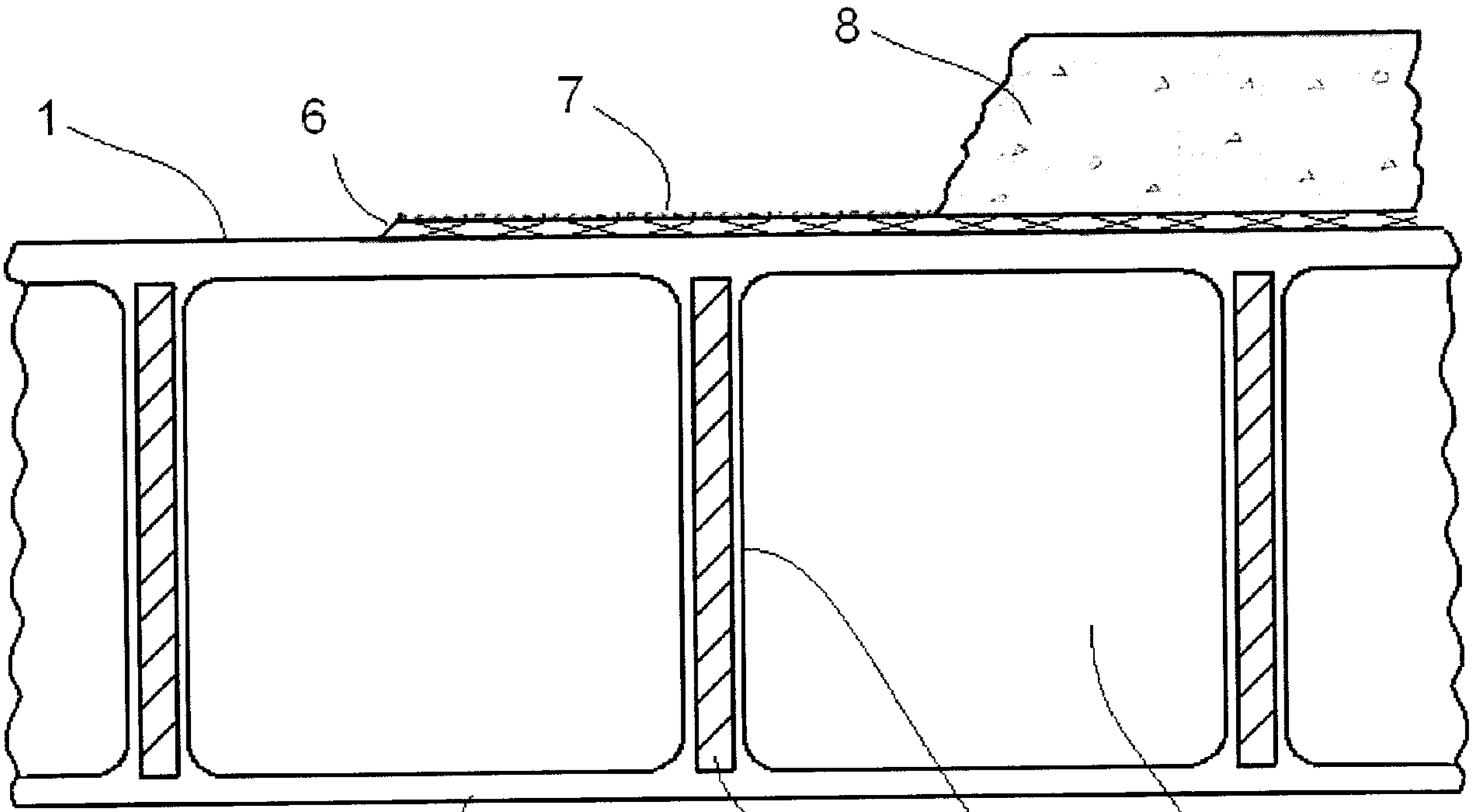


Figure 9C

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